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Implications of a vanishing Gauss-Bonnet invariant in $f(G)$ gravity: the quadratic case

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It is well known that Lovelock polynomials including the special case of second order Gauss-Bonnet (G) invariants are topological and do not contribute to the dynamics of physical entities in four spacetime dimensions. Efforts to include higher curvature effects through dimensional regularization schemes in four dimensions are ongoing though several mathematical hurdles must be overcome. Another direction to incorporate higher curvature is to investigate functional forms of the Gauss-Bonnet invariants through the so-called $f(G)$ gravity. This is the object of our study. We exploit an important property of the Lovelock terms that of containing up to second order derivatives irrespective of the order of the polynomial. The linear order $f(G) = G$ corresponds to

Einstein gravity in 4 dimensions and standard EGB gravity for higher dimensions. However the next level the pure quadratic case $f(G) \sim G^2$ offers intriguing possibilities. But before we probe this we note a little known fact that the Gauss-Bonnet term itself contains up to second order derivatives of the metric potentials. This then opens up the interesting question of which spacetime geometries will cancel the higher curvature effects in the four dimensional spacetime manifold but not in the physics. The derivatives of G still live on in the thermo-dynamical quantities and influence their behavior. We identify such geometries that produce this effect and examine how the physical properties are impacted. (Geometrically we will be living in a 4D Einstein world but physically we will be feeling the effects of extra curvature through the GB contributions).

Author: NYANDENI, Siphelele (University of KwaZulu-Natal)

Co-author: Mr HANSRAJ, Sudan (Co Author)

Presenter: NYANDENI, Siphelele (University of KwaZulu-Natal)